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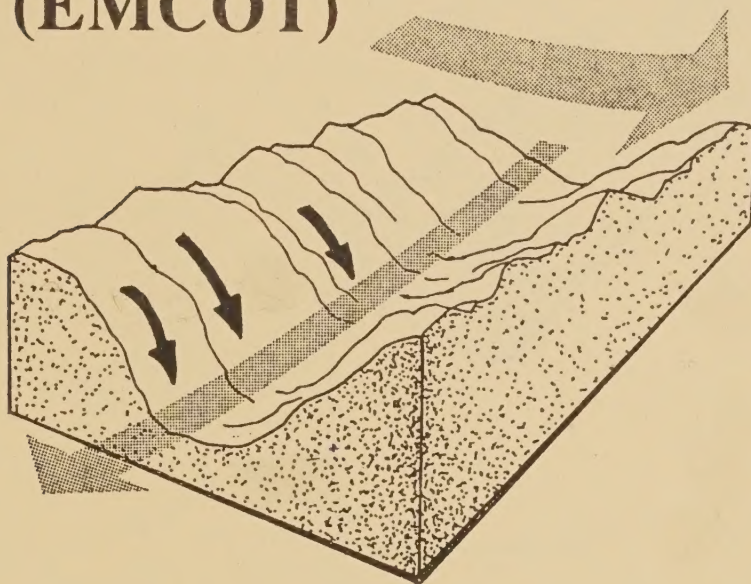
Forest Service

Technology &  
Development  
Center

Missoula, MT



# PROGRAM WIND: EVENT MODELING FOR COMPLEX TERRAIN (EMCOT)



March 1989  
3400—Forest Pest Management  
MTDC 89—8

United States  
Department of  
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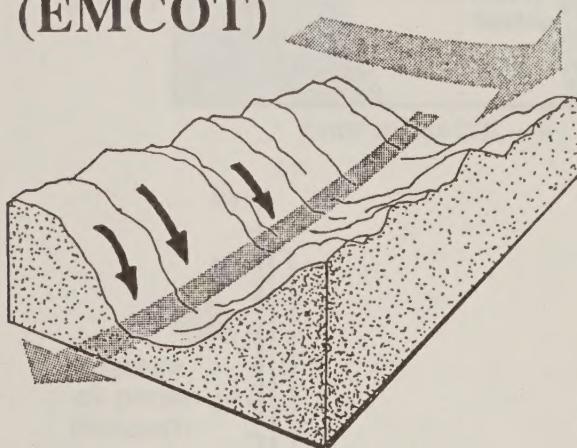


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# PROGRAM WIND: EVENT MODELING FOR COMPLEX TERRAIN (EMCOT)



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**Missoula, MT 59801**

**MARCH 1989**

*(This work was done under Program WIND)*

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## Pesticide Precautionary Statement

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

**Caution:** Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.





## Introduction

The USDA Forest Service has developed two computer based models to predict the behavior of aerially released pesticides. The two models are AGDISP and FSCBG. Participation in Program WIND provided a unique opportunity to conduct dispersion testing while intensive large scale meteorological measurements were being taken. This in turn enabled us to verify and extend aspects of the models that are very dependent on meteorological measurements.

It also provided an opportunity to examine the possibility of developing a systematic, organized approach to predict the evolution of events within the boundary layer that begin with sunrise and terminate with turbulence and rising convective air that eventually makes it impossible to continue effective aerial spraying.

We have termed this approach EMCOT, Event Model For Complex Terrain. It is an extension of the valuable empirical knowledge that field personnel have acquired about conducting spray projects in mountainous terrain. In that sense it is more akin to an artificial intelligence model than a Lagrangian or Eulerian behavior model.

The information, and recommendations which follow will be a more detailed description of EMCOT, the dispersion trials, and meteorological measurements that were made during the field phase of Program WIND to develop the EMCOT concept.

The purpose of the study was to determine if these are measureable trends in the atmospheric processes that can be used in the predictive model EMCOT. A second purpose was to provide experimental verification of the model AGDISP and information on vortex decay for model inputs. These efforts are successfully completed (Ekblad, 1988; Bilanin and Teske, 1989).

## EMCOT Model

### Spraying Scenario

Aerial spraying is generally avoided immediately before, during, and after major weather disturbances because of poor flying conditions and likelihood of moisture. It is generally true that most spraying will be done during fair weather with clear skies. The solar radiation leads to local heating that generates turbulence and rising air that makes aerial spraying difficult during midday. The primary spray window is from daylight until radiation induced turbulence prohibits flying or settling of the spray (usually a period of about 3 hours). The occasional presence of a scattered or high thin cloud cover will extend the time as much as 4 hours.

A typical spray is composed of a range of drop sizes. The larger drops are controlled predominantly by gravitational settling; the smaller drops are influenced by air movement (figure 1). Near aircraft, drops of all sizes are subject to strong violent perturbations from aircraft. As this influence decays, gravity and air movements dominate the drop trajectories. Figure 2 depicts the organized airflow behind the aircraft that contains the airborne drops.

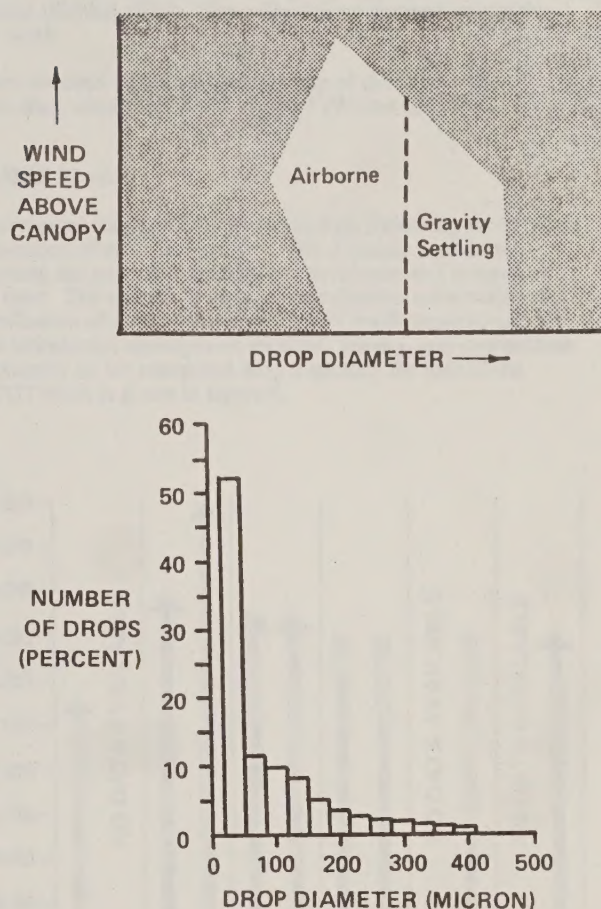


Figure 1.—A typical distribution of spray drop sizes.

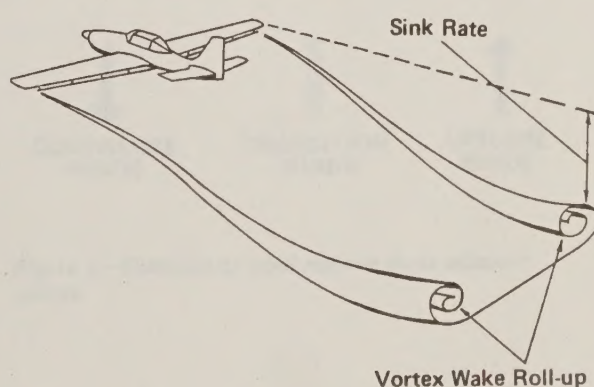


Figure 2.—Organized airflow from subsonic aircraft.

Note: This report was originally presented as a paper at the 19th National Conference on Agricultural and Forest Meteorology, March 7-10, 1989, at Charleston, South Carolina.





During clear, fair-weather days, winds in mountain valleys begin with an established regime of downslope, downvalley winds (figure 3a). At sunrise the earth's surface warms in response to solar heating. The amount and timing of surface warming depends on cloud shading and on the geometry of earth-based shadowing. The shallow surface layer of air is in turn warmed and slope winds begin to reverse from downslope to upslope (figure 3b). As heating continues, stirring and mixing breaks the inversion layer and both upslope and upvalley winds appear through the valley (figure 3c). The winds within the valley are coupled with the gradient winds and influence the final wind direction in the valley.

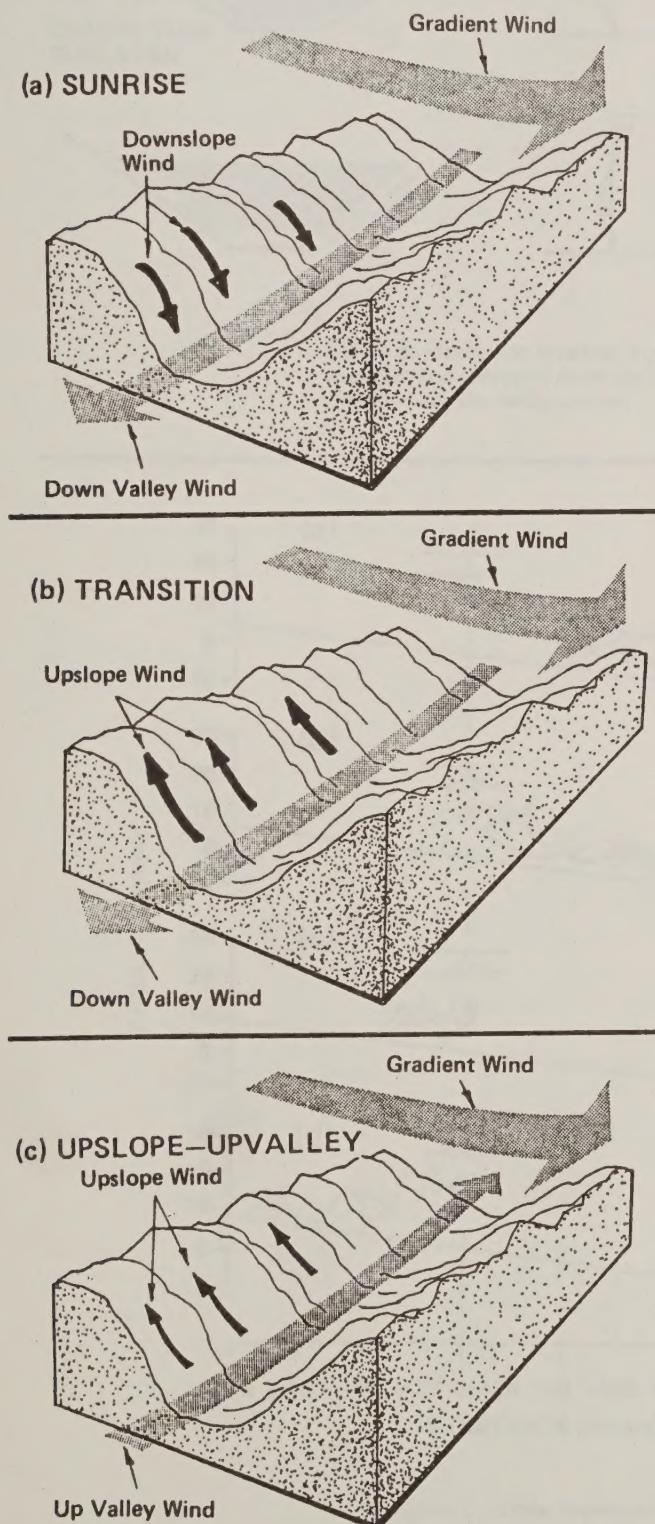


Figure 3.—Time sequence of winds in complex terrain.

Figure 4 shows the duration of each sequence for two points measured in adjacent valleys during a spray project near Helena, Montana (Ekblad 1977). The valleys were sprayed within the same week.

A more detailed version of the breakup of the stable core of downvalley wind is shown in figure 5 (Whiteman 1982).

The computer model AGDISP is based on following the location and motions of discrete particles. The dynamic equations governing the particle trajectory are developed and integrated over time. The equations include very detailed information on the influence of aircraft dispersal system configuration; aircraft wake turbulence, atmospheric motions, gravity, and evaporation. An example of the computed drop trajectory for four of the EMCOT trials is given in figure 6.

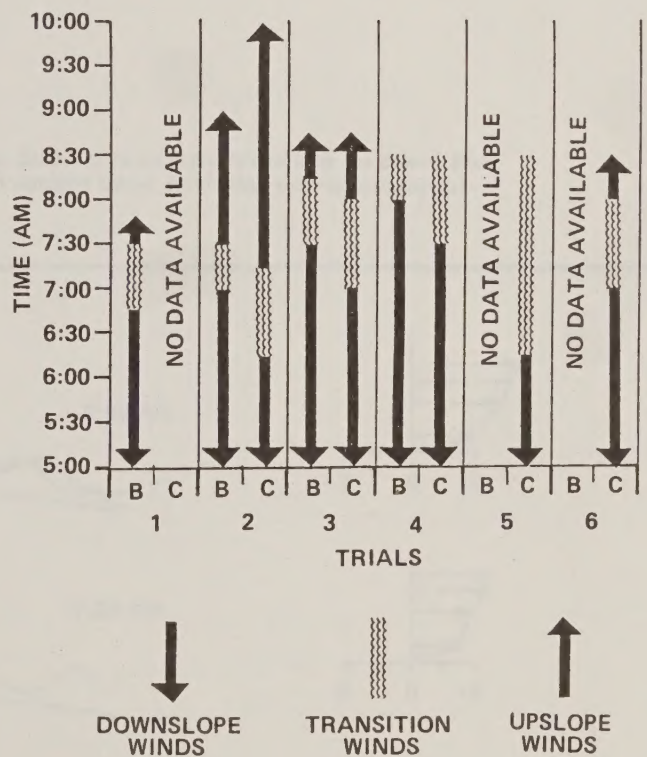


Figure 4.—Duration of wind regimes in six adjacent valleys.





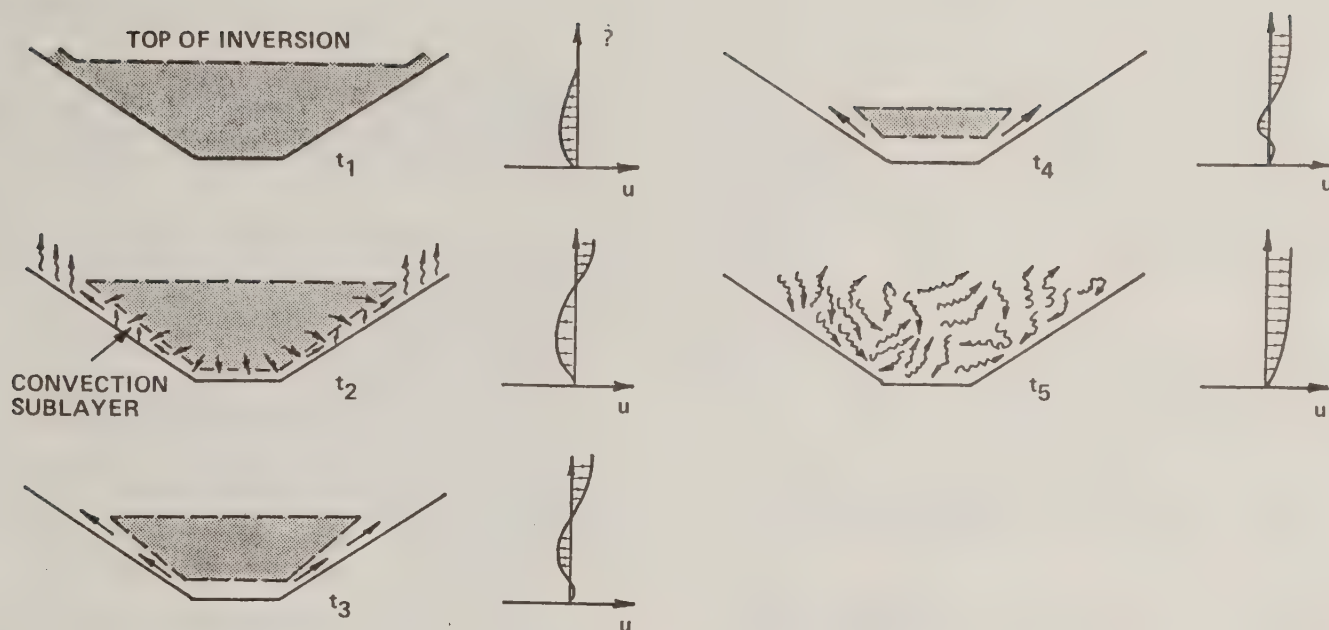


Figure 5.—Inversion breakup hypothesis. Stable core air is entrained into the convection sublayer and removed from the valley in upslope flows, producing a compensating subsidence over the valley center.

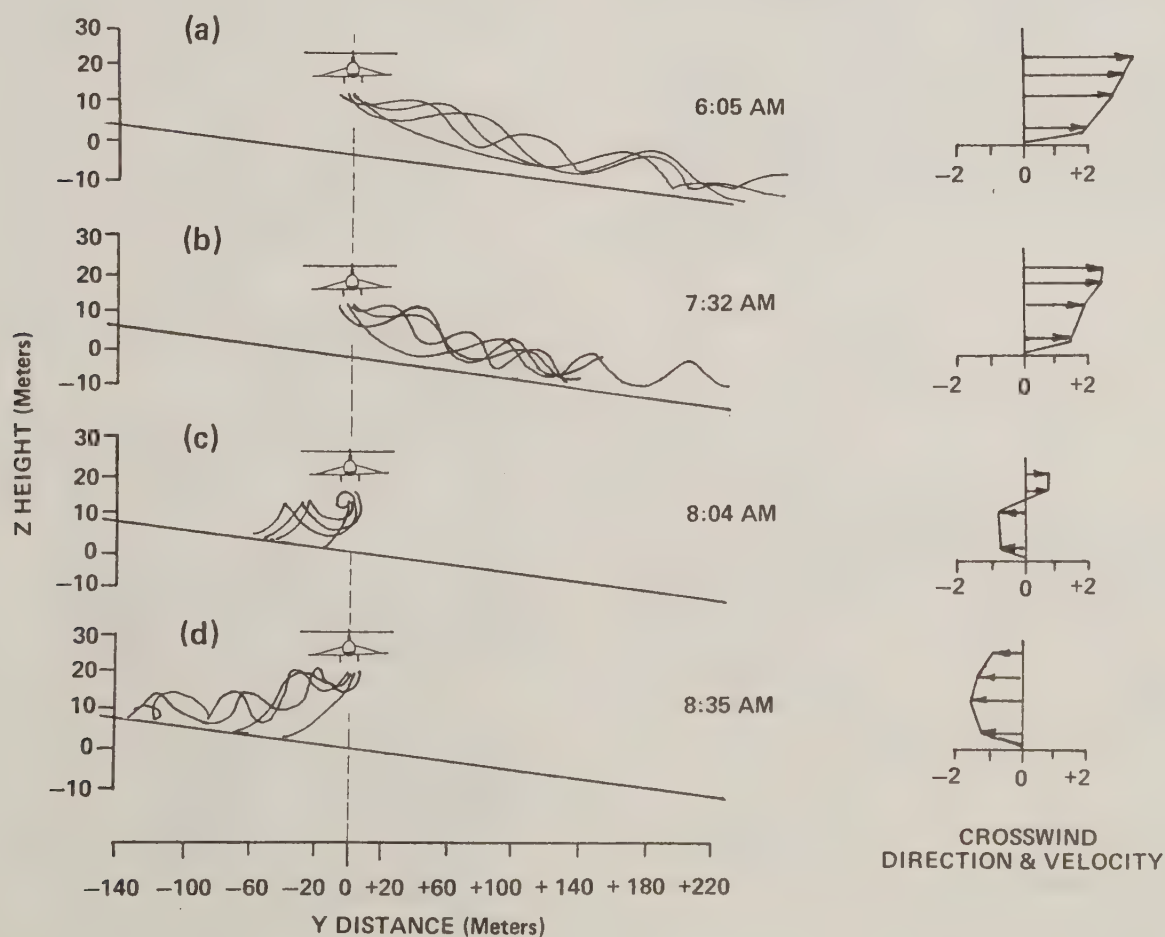


Figure 6.—Drop trajectories for four consecutive EMCOT trials.





EMCOT Concept

One of the most critical elements of aerial spraying in mountainous terrain is predicting when spraying should stop each day. Accurate prediction is important because of the lag-time involved in mixing, loading, ferrying, and application after the first observation that the spray is not reaching the target (Ekblad 1976).

Figure 7 is a plot of the average vertical component of windspeed between the spray aircraft and the target area, during the course of a typical spray morning. In figure 8a, the average vertical wind component from the aircraft is plotted as a straight line. In figure 8b, the vertical wind component generated by atmospheric forces is shown during a typical morning. The three lines depict variations in upward bouyancy from diminished solar heating due to cloud cover. A similar effect from coupling with gradient winds is shown in figure 8c.

In figure 8d, the aircraft downwash velocities and atmospheric values are combined. The three events that are of importance are the ending of the downslope, beginning of the upslope, and the time when the drop velocity from the aircraft is overcome by atmospheric forces and will not descend to the target.

The variations within a single valley are shown by three different lines that yield three different values for event three. This information will be used to schedule mixing, loading, and spraying of various units.

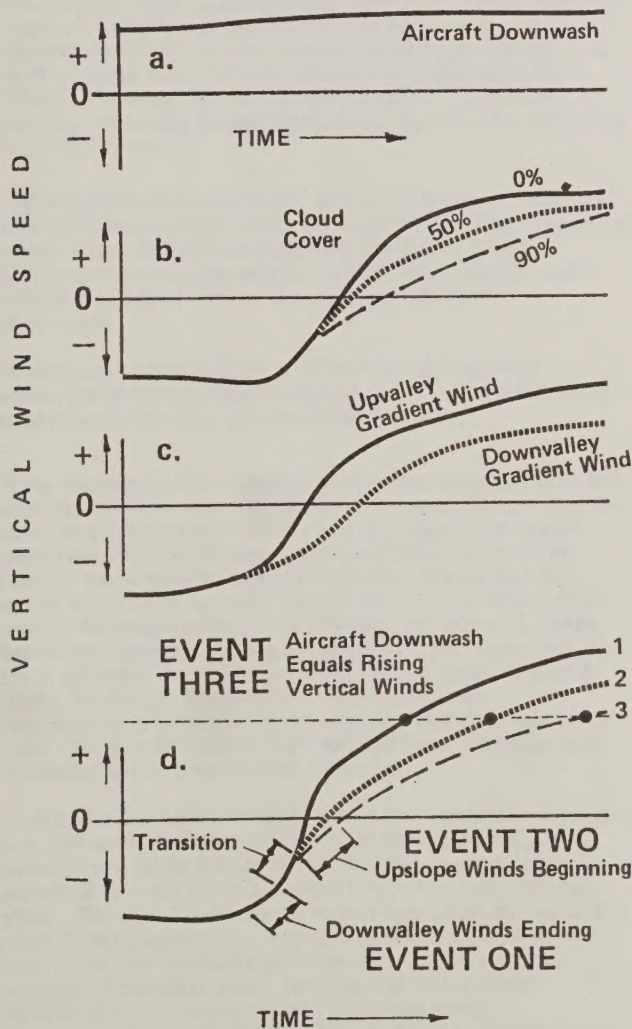


Figure 8.—Conceptual view of event model for complex terrain (EMCOT).

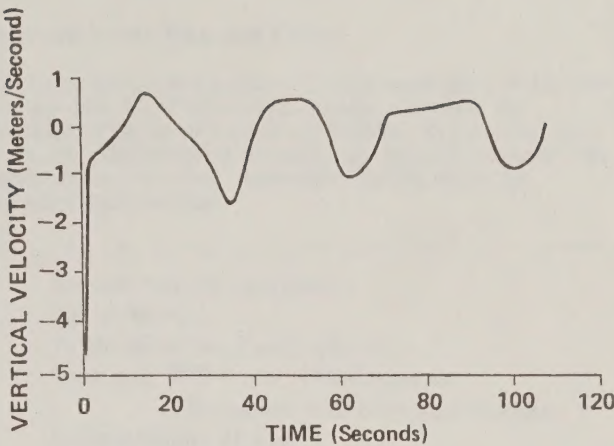


Figure 7.—Downward velocity of spray drop induced by aircraft downwash.

EMCOT Spray Trials

Study Design

The aircraft wake and dispersion test used an area of moderately complex topographical features that is part of the Program WIND Forest Site. This area consists of a pair of ridges. A small, intermittent stream runs between the ridges and leads outward from the forested area of the site through the test area itself. The test area is planted with small coniferous trees.

Forest Tower 1 is located at the top of the northernmost of the two ridges in the cleared area. This ridge leads generally westward across a roadway to a small headland where Border Campbell 2 is located. The southern ridge also leads generally westward across the same roadway to a second small headland where both Border Campbell 3 and the site for taking Forest Site GMD and acoustic sounder observations are located (figures 9 and 10) (Hauser 1988).

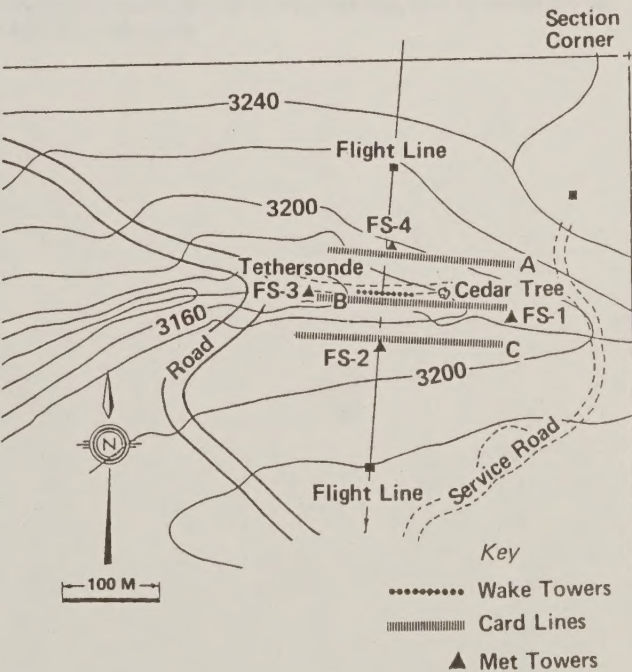


Figure 9.—Map of EMCOT study site.







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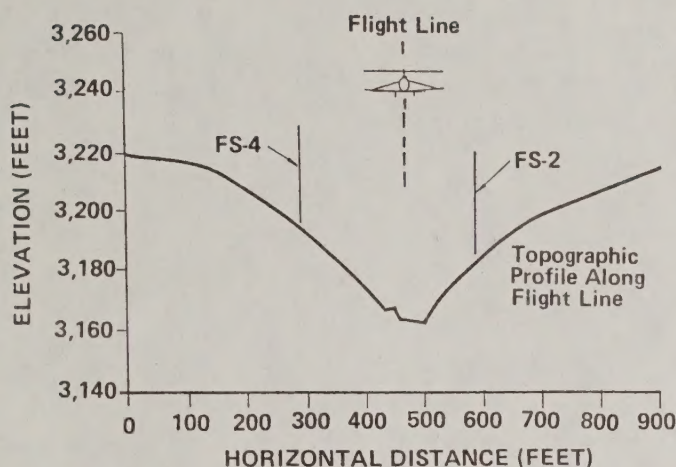


Figure 10.—Cross section of terrain under flight line.

The test site is well anchored with Program WIND tower sites that record meteorological data both as 1-minute averages and as more frequent point samplings of sensor output at several levels above ground level.

The stream, ridges, and headlands complex are a small part of a larger set of topographical features that lead systematically southwestward and broaden into an area of larger flatlands and creek canyons which, in turn, lead directly to the Sacramento Valley. The immediate topographical relief is sufficient to generate interesting upslope and downslope flows without being too complicated.

The dispersion and wake vortex area is open and accessible and was easily instrumented with both meteorological and dispersion measurement devices at a reasonable number of points. Observations of upslope and downslope wind behavior, wake behavior, and dyed-droplet distributions were made successfully.

Helicopter operations at 30- to 40-minute intervals were conducted to bracket dawn transition events that rapidly change temperature, heat-flux, and turbulent intensities.

Wake measurement towers equipped in the downslope axial and vertical directions with Gill anemometers were placed along the streambed between the roadway and an isolated tree located about two-thirds of the way across the Christmas tree farm. Four 10-meter meteorological towers were placed near the stream axis east of the wake towers, one near the stream axis west of the towers and near the roadway, one about 15 meters below the northern ridge top on the south-facing slope, and one about 15 meters below the southern ridge on the north-facing slope. To provide finer-grained temporal resolution observations of the boundary-layer profile along the axis of the small stream, a tether sonde was operated from a location near the stream axis and west of the roadway.

Each of the four meteorological towers was equipped with three-axis Gill anemometers at the 10-meter level, light-weight cup anemometers at the 2-meter level, shielded air temperature sensors at both the 10- and 2-meter levels, and with heat flux plates. The two meteorological towers located on the north- and south-facing slopes also equipped with solar radiation sensors. Each of the four meteorological towers acquired 1-minute averages of 1-second sensor samples, and each recorded windspeed at 2-second intervals. The wake tower instrumentation functioned in a manner that is similar to the two wake and dispersion experiments that were conducted in California during the summer 1985 Project WIND period (Williams, 1986).

## Aircraft Spray Plan and Tracer

Each trial consisted of a series of single swath spray flights over the test area. The flights began as early as possible and continued until the air became too turbulent for spraying. Data were collected separately for each flight including deposit cards and drift measurements. Approximately four flights are expected each morning.

Aircraft: Bell 206 helicopter  
 Speed: 60 mph  
 Application rate: 2 gallons/acres  
 Tank mix: 67% Water, 33% Glycerine  
           2 lbs./gallon No.2 Blue food coloring  
 Release height: 75 feet  
 Atomizer: Hollow Cone nozzles D8-45  
 Nozzle orientation: Straight back  
 Target VMD: 375 microns

## Spray Deposit Sampling and Assessment

White spray deposit cards were placed on or near the ground in three parallel lines. Within the lines the cards were at 10-foot intervals.

## Results

The meteorological data for April 30, 1986 have been reduced and analyzed (Hauser, Ekblad, Barry 1988). Final analysis of the data that will include spray behavior and droplet deposition remains to be completed. For purposes of illustration the primary variables from the tower at the head of the test site drainage, FS-1, are shown in figure 11. Results of the analysis are beyond the scope of this paper, but the authors were able to conclude that there was a coherent sequence of events that characterize the early morning transition in moderately complex terrain. All of the analysis was done on a personal computer that could be readily deployed into the field. A modified three-dimensional stability ratio is proposed that may be useful for the EMCOT predictions.





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